359-346 AU 2507 49202

(GB002247323A) GB 002247323 A
(FEB 1992) FEB 1992

(W)

(12) UK Patent Application (19) GB (11) 2 247 323 (13) A

(43) Date of A publication 26.02.1992

(21) Application No 9015970.8

(22) Date of filing 20.07.1990

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(51) INT CL[5]
G02B 7/185

(52) UK CL (Edition K)
G2J JMH

(56) Documents cited
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(58) Field of search
UK CL (Edition K) G2J JMA JMH
INT CL[5] G02B

(54) Variable shape telescopic mirror

(57) A telescope mirror 10 comprises a substrate 11 with a reflecting surface 12 and having a network of electrical conductors 14 located in a magnetic field. By supplying respective adjustable electrical current to the individual conductors, the mirror is constrained to adopt a desired shape. The mirror may comprise a plurality of discrete segments 20 e.g. concentric annuli separated by magnetic poles.

FIG.1

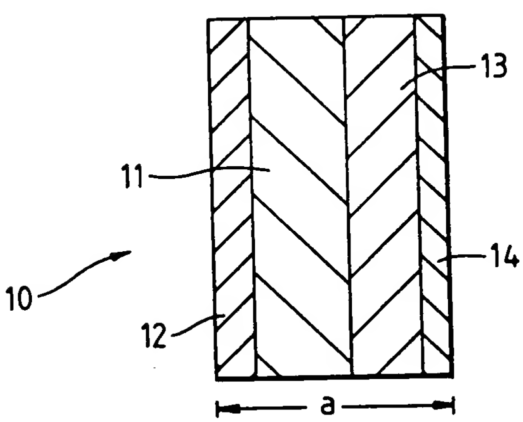
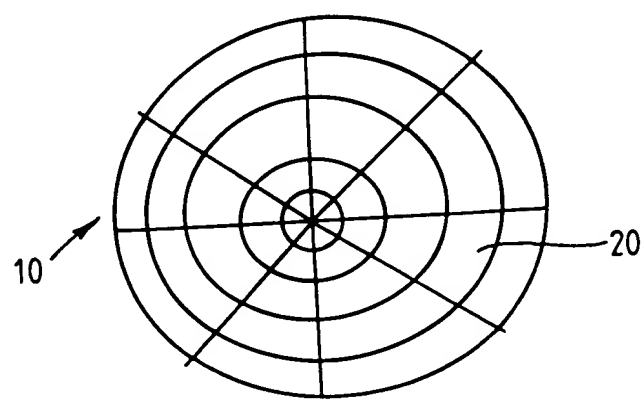


FIG.2



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1990.

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FIG.1

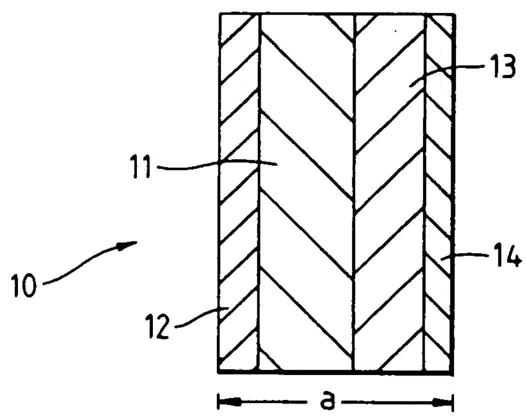
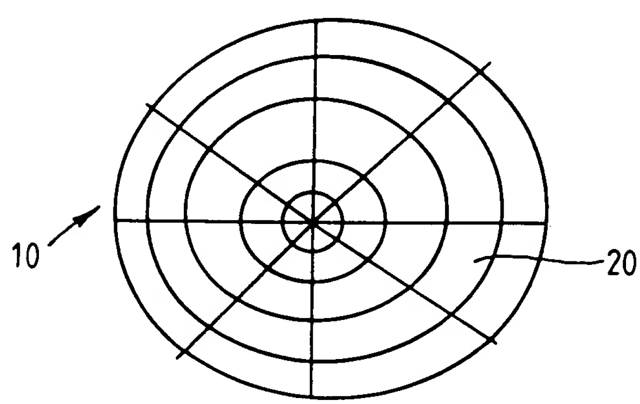


FIG.2



Telescopic Mirror

The present invention relates to a telescopic mirror and more particularly to a mirror which has variable focal length and which is actively controlled.

For relatively large mirrors it is desirable to be able to move adjacent parts of the mirror surface relative to each other, firstly to be able to adjust the focal length of the mirrors, and secondly to be able to correct for errors in the shape of the surface compared to a particular desired shape, e.g. errors introduced by gravitational effects as the inclination of the mirror is changed.

It is known to provide a segmented mirror, the individual segments of which are controlled by mechanical actuators. However, such an arrangement is relatively cumbersome, since the actuators are heavy and occupy a large space. Accordingly the response time is also slow. Also, since the individual segments are relatively large, a high number of discontinuities are introduced into the surface of the mirror. In addition to this, it is difficult to produce either fixed or segmented mirrors with an off-axis focus.

The present invention seeks to overcome or reduce one or more of the above disadvantages.

According to a first aspect of the present invention there is provided a mirror for use in a telescope comprising a substrate with a reflecting surface, the substrate comprising electrically insulating material

carrying a network of electrical conductors, a magnetic field source, and means for supplying adjustable respective electrical currents to the individual conductors of said network.

The current supply means may incorporate means for detecting the actual shape of the mirror and correcting any deviations from a desired shape.

The basic principle of operation of the mirror is that currents flowing in the region of a magnetic field experience a force on them. If this is coupled with the information that when a flat sheet is subjected to a slight deformation, the resultant figure is paraboloidal to a first approximation, with corrections being usually of the fourth order and above, the operation of the mirror becomes evident. By passing a current through an appropriate network of conductors, e.g. on the rear surface of the mirror, the mirror is deformed to a paraboloidal shape, the depth and curvature of which can be controlled electrically as required. Each independent conductor gives an extra degree of freedom and hence of control of the mirror shape.

The network need not be purely two-dimensional i.e. layers of radial or transverse conductors can be built up if separated by deposition of a suitable insulator. The currents need not be very high since the support can be made sufficiently thin so that very small forces are required to deform it. The tendency to sag under its own weight asymmetrically if raised out of horizontal position can be actively compensated by the control system.

For mirrors of very large diameter, the magnetic field strength may not be sufficiently uniform or strong to produce the desired result. In this case the mirror can comprise a plurality of thin concentric annuli separated by alternating magnetic pole pieces, since the mirror surface does not need to be continuous, but rather to lie a paraboloidal envelope.

According to a second aspect of the present invention there is provided a method of controlling the shape of a mirror for a telescope comprising a substrate with a reflecting surface, the substrate comprising electrically insulating material carrying a network of electrical conductors, and a magnetic field source, the method comprising detecting the actual shape of the mirror and supplying respective electrical currents to the individual conductors of said substrate so that the mirror has a desired shape.

A preferred embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawings, of which:

Fig.1 shows an enlarged sectional view of part of a mirror in accordance with the present invention; and

Fig.2 shows on a small reduced scale a rear view of the mirror of Fig.1.

Referring to the drawings, Fig 1 shows a cross-section of a segment of a mirror 10 comprising a substrate 11 having a silvered or other optically reflective surface 12 and, on its other face, an insulating layer 13 carrying a network of conductors 14. The thicknesses

of the various layers are not necessarily shown to scale, but the total thickness "a" is approximately 1mm.

Fig.2 shows one possible arrangement of a plurality of segments 20 which form a complete mirror 10. The entire mirror has a diameter of several metres.

The substrate 11 constitutes an inert smooth base, for example a thin sheet of metal, polished to a high finish. The rear of the mirror is coated with an insulating substance 13 either by bonding, spraying, vacuum deposition before the conducting network is applied. Deposition of ultra-thick circuitry on the rear surface ensures that it is capable of supporting relatively large currents.

The reflective coating 12 may be of aluminium deposited by vacuum evaporation, which is controlled to produce an optically smooth surface.

The mirror 10 has one or more magnetic field sources surrounding it and/or behind it. Relatively powerful electromagnets or superconducting magnets can be employed and may produce linear and/or radial magnetic field components. There is also provided figure-monitoring equipment (not shown) which detects and monitors the actual shape of the mirror. This monitoring equipment is connected to electronic control apparatus (not shown) which supplies individual control currents to the conductors 14 of the network to control the position of the mirror segments 20 so that the mirror 10 adopts and maintains its desired shape. The electronic control apparatus is hardwired as far as

possible with the remainder of the optimisation process being effected by software in real time.

The above-described mirror has a number of advantages. Because the mirror itself is very thin it is also very light, and this low mechanical inertia leads to a fast response time. The figure of the mirror is continuously monitored optically, and using feedback techniques in which appropriate error signals are minimised, the mirror shape is controlled electrically to conform to a prescribed value within certain limits.

Another advantage of the thinness of the mirror is that, whether or not adjacent segments of the reflecting surface 12 are discrete, any discontinuities between them are very small; since the corrective forces are distributed in a continuous fashion, and not discretely as in mechanically driven mirrors, this also gives a smoother surface with fewer discontinuities. Moreover, the lightness of the mirror means that it lends itself well to satellite applications where its variable focal length and light weight are particularly suitable.

In addition, the method of making the mirror lends itself well to the production of the asymmetric shapes necessary to produce an off-axis focus. Indeed almost any required smooth shape is achievable, including convex mirrors used as secondary mirrors.

Numerous modifications may be made to the above-described arrangement. Any or all of the layers 11,12,13 may be discrete or continuous over the entire mirror. They may comprise a plurality of thin

concentric annuli. This arrangement is particularly suitable when a single source magnetic field is insufficiently strong or uniform, in which case the annuli can be separated by magnetic field sources e.g. alternating magnetic pole pieces. Other measures for overcoming the problems of a non-uniform field include making the mirror thinner remote from the magnets and arranging for higher electric currents to pass through parts of the network remote from the magnets.

The extent of each conductor 14 depends upon the desired degree of control required. The network may be in two or three dimensions and may be embedded in the insulating layer 13 instead of or in addition to being on its surface. Substrate 11 may itself be of insulating material, e.g. plastics, in which case layer 13 can be omitted and the conductors 14 can be on and/or in the substrate itself.

The control arrangement can be used in applications other than telescopes, where the relative positions of segments of a large surface need to be controlled.

CLAIMS

1. A mirror for use in a telescope comprising a substrate with a reflecting surface, the substrate comprising electrically insulating material carrying a network of electrical conductors, a magnetic field source, and means for supplying adjustable respective electrical currents to the individual conductors of said network.

2. A mirror according to claim 1 wherein the current supply means comprises means for detecting the actual shape of the mirror and correcting any deviations from a desired shape.

3. A mirror according to claim 1 or 2, wherein the network of conductors is on the rear surface of the mirror.

4. A mirror according to claim 1 or 2, wherein the electrical conductors in the network are arranged in a plurality of layers separated by insulating material.

5. A mirror according to any preceding claim comprising a plurality of discrete mirror segments.

6. A mirror according to claim 5, wherein the segments are arranged in the form of concentric annuli.

7. A mirror according to claim 6 wherein the annuli are separated by magnetic field sources.

8. A mirror according to any of claims 1 to 5 wherein parts of the mirror remote from the magnetic field source are thinner than the parts of the mirror adjacent to the magnetic field source.

9. A mirror substantially as herein described with reference to the accompanying drawings.

10. Method of controlling the shape of a mirror for a telescope comprising a substrate with a reflecting surface, the substrate comprising electrically insulating material carrying a network of electrical conductors, and a magnetic field source, the method comprising detecting the actual shape of the mirror and supplying respective electrical currents to the individual conductors of said substrate so that the mirror has a desired shape.

11. A method according to claim 10 wherein the desired shape of the mirror is asymetric.

12. A method of controlling the shape of a mirror or a large surface substantially as herein described with reference to the accompanying drawings.

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